OPEN-FILE REPORT 2000-006

SEISMIC HAZARD EVALUATION OF THE ONTARIO 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

2000

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

STATE OF CALIFORNIA
GRAY DAVIS
GOVERNOR

THE RESOURCES AGENCY
MARY D. NICHOLS
SECRETARY FOR RESOURCES

DEPARTMENT OF CONSERVATION
DARRYL YOUNG
DIRECTOR

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS, *STATE GEOLOGIST*

OPEN-FILE REPORT 2000-006

SEISMIC HAZARD EVALUATION OF THE ONTARIO 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

DIVISION OF MINES AND GEOLOGY'S PUBLICATION SALES OFFICES:

Southern California Regional Office
655 S. Hope Street, Suite 700
Los Angeles, CA 90017
(213) 239-0878

Publications and Information Office
801 K Street, MS 14-31
Sacramento, CA 95814-3531
(916) 445-5716

Bay Area Regional Office
185 Berry Street, Suite 210
San Francisco, CA 94107-1728
(415) 904-7707

CONTENTS

ILLUSTRATIONS

PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

DIVISION OF MINES AND GEOLOGY OFFICES

Geologic Information and Publications Office
801 K Street, MS 14-33
Sacramento, CA 95814-3532
(916) 445-5716

Bay Area Regional Office
185 Berry Street, Suite 210
San Francisco, CA 94107-1728
(415) 904-7707

Southern California Regional Office
655 S. Hope Street, Suite 700
Los Angeles, CA 90017
(213) 239-0878

WORLD WIDE WEB ADDRESS

Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Ontario 7.5-minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Ontario 7.5-Minute Quadrangle, Los Angeles County, California

By
Ralph Loyd

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Ontario 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments within the upper 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the Ontario Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Ontario Quadrangle covers an area of about 62 square miles of mostly gently sloping terrain that straddles the Los Angeles and San Bernardino County boundary. The 15-square-mile area of valley-floor terrain evaluated for liquefaction hazards lies within the Los Angeles County part of the quadrangle. (Federal funding for the program limits the investigation to Los Angeles, Orange, and Ventura counties; therefore, the County of San Bernardino is not covered by the current study.) The study area encompasses a small part of the upper Santa Ana River valley, which is a roughly 40-mile long, 10-mile wide structural basin that extends along the southern base of the mountains between Pomona and San Bernardino. Just north of the Ontario Quadrangle, in the Mt. Baldy Quadrangle, the San Gabriel Mountains rise abruptly above the valley floor.

The notable drainage eminating from the San Gabriel Mountains and flowing through the project area is San Antonio Creek. Materials eroded from the mountains and deposited in the valley via this drainage and its tributaries have formed a large alluvial fan upon which lie the cities of Claremont and Pomona in Los Angeles County.

Except for 1.5-square miles in the southwestern corner of the quadrangle occupied by the Puente Hills (in San Bernardino County) and a tiny projection of the mountain front into the northwesternmost corner, the project area consists of relatively flat, densely populated land. Major transportation routes traversing the Ontario Quadrangle include the San Bernardino Freeway (I-10) and the Pomona Freeway (State Highway 60). Major east-west streets in the project area include Base Line Road, Foothill Boulevard, Arrow Highway, and Holt Avenue. Important north-south streets include Garey, Towne, and Indian Hill boulevards.

GEOLOGIC CONDITIONS

Surface Geology

A Quaternary geologic map of the Ontario Quadrangle was obtained in digital form from the Southern California Areal Map Project (SCAMP,1999). SCAMP nomenclature was used for labeling geologic units (Morton and Kennedy, 1989). The Quaternary geologic map of the Ontario Quadrangle is reproduced as Plate 1.1.

The Quaternary geologic map (Plate 1.1) shows that the valley surface within the Los Angeles County portion of the Ontario Quadrangle is covered by fine- to very coarse-grained alluvial deposits that constitute the large alluvial fan developed by San Antonio Creek. The alluvial fan deposits are subdivided into several subunits that reflect dominant grain size and relative age (Table 1.1).

Subsurface Geology and Geotechnical Characteristics

Subsurface data used for this study include borehole logs collected from the California Department of Transportation (CalTrans), the California Department of Water Resources, the Regional Water Quality Control Board, Los Angeles County Flood Control files by U.S. Geological Survey staff, DMG files of seismic reports for hospital and school sites, and a database of shear wave velocity measurements originally compiled by Walter Silva (Wills and Silva, 1998).

About 100 logs of boreholes drilled within the study area were collected, examined and related to the surficial geologic map units. Locations and geotechnical data from borehole logs were entered into DMG's Geographic Information System (GIS). Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. Construction of cross sections using data reported on the borehole logs enabled staff to relate soil engineering properties to various depositional units, to correlate soil types from one borehole to another, and to extrapolate geotechnical data into outlying areas containing similar soils.

Major findings from the subsurface evaluation are: (1) although the upper part of the San Antonio Creek fan (north of Holt Avenue) is dominated by gravel-, cobble-, and boulder-rich deposits, interbeds of sand, silt, and clay locally occur in the section; (2) alluvial fan deposits are dominated by silt, sand, and clay south of Holt Avenue; and (3) the younger Quaternary alluvial sediments in the Los Angeles County part of the Ontario Quadrangle do not extend to great depths. Lithologic descriptions in borehole logs indicate the presence of older, firm/dense sedimentary deposits at depths of between 10 and 30 feet.

Map Units	Environment of Deposition	Age
Qw	active wash	historic time
Qyf1, Qyf2, Qyf3	young alluvial fan	Holocene
Qof	older alluvial fan	Late Pleistocene
Qvof	very old alluvial fan	Pleistocene

Some unit names include the "characteristic grain size" (e.g. Qyf2a, Qofg)
b: boulder-cobble, g: gravel, a: arenaceous (sand), s: silty, c: clayey.

Table 1.1. Units of the Southern California Areal Mapping Project (SCAMP) nomenclature used in the Ontario Quadrangle.

GROUND-WATER CONDITIONS

Liquefaction hazard mapping focuses on areas historically characterized by ground-water depths of 40 feet or less. Accordingly, a ground-water evaluation was performed to determine the presence and extent of historically shallow ground water in the Ontario Quadrangle. Data required to conduct the evaluation were obtained from technical publications, geotechnical boreholes, and water-well logs dating back to the turn-of-the-century, namely 1904 ground-water contour maps (Mendenhall, 1908), shallow ground-water maps included in Leighton and Associates (1990), and ground-water contour maps prepared by Carson and Matti (1985) based on 1973-1979 measurements.

Water-table elevations reported in Mendenhall (1908) show that shallow ground-water conditions existed in the vicinity of Interstate 10 at the western margin of the quadrangle. This condition appears to be the result of a restriction of groundwater flow on the north side of the San Jose Fault (Plate 1.1). Similar conditions are present in the southern Pomona area where ground-water flow is restricted on the west side of the Chino Fault. Here, several ground-water measurements record depths that range between 14 and 28 feet.

Carson and Matti (1985) show that historical shallow ground-water levels exist in two isolated areas in the central part of the city of Claremont (Plate 1.2), but they could not determine whether the conditions were due to damming by adjacent ground-water barriers (San Jose and Indian Hill faults), perched water, artesian conditions within a confined acquifer, or a combination of factors. Subsequently, geotechnical drilling conducted in the more southern area of Claremont in 1986 encountered "confined perched groundwater" at 11 feet and again at 45 feet depth (California Department of Conservation, Division of Mines and Geology, 2000; record official name: "000050_00014_34117A6").

Carson and Matti (1985) also identify shallow ground-water conditions occurring along the base of the San Gabriel Mountains in the northwestern part of the City of Claremont. Here, Quaternary sediments are periodically saturated by ground water apparently perched on the underlying bedrock surface. The boundaries of this shallow ground-water area continue northeastward into the adjoining Mt. Baldy Quadrangle.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water-saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period. The earthquake magnitude is the magnitude that contributes most to the acceleration.

For the Ontario Quadrangle, a peak acceleration of 0.47 to 0.56 g resulting from an earthquake of magnitude 6.7 to 6.9 was used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. These properties and conditions are correlated with geologic age and environment of deposition. With increasing age of a deposit, relative density may increase through cementation of the particles or the increase in thickness of the overburden sediments. Grain size characteristics of a soil also influence susceptibility to liquefaction. Sands are more susceptible than silts or gravels, although silts of low plasticity are treated as liquefiable in this investigation. Cohesive soils are generally not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in lower liquefaction susceptibility generally result in higher penetration resistances to the soil sampler. Different blow count corrections are used for silty sand and nonplastic silt than for clean sand (Seed and others, 1985). Therefore, blow count or cone penetrometer values are a useful indicator of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (more likely to liquefy). Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-property and soil-condition factors such as type, age, texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, findings can be related in terms of the map units. DMG's qualitative susceptible soil inventory is summarized on Table 1.2.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and others, 1985; National Research Council, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site related structures. For a regional assessment DMG normally has a range of FS that results from the liquefaction analyses. The DMG liquefaction analysis program calculates an FS at each sample that has blow counts. The lowest FS in each borehole is used for that location. These FS vary in reliability according to the quality of the geotechnical data. These FS as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil are evaluated in order to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation.

Geologic Map Unit	Sediment Type	Environment of Deposition	Consistency	Susceptible to Liquefaction?*
Qw	sand, gravel, cobbles, and boulders	Active stream channels	loose	yes
Qyf, Qyf1-3,	boulders, cobbles, gravel, sand, minor silt and clay	Young alluvial fans and valley deposits	loose to moderately dense	yes
Qof, Qvof	cobbles, gravel, sand, silt, and clay.	older alluvial fans and valley deposits	dense to very dense	not likely

* When saturated.

Table 1.2. General geotechnical characteristics and liquefaction susceptibility of Quaternary sedimentary units.

Of the 100 geotechnical borehole logs reviewed in this study (Plate 1.2), 20 include blow-count data from SPT's or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using logged density, moisture, and sieve test values or using average test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.

2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.

4. Areas where existing geotechnical data are insufficient.

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the Ontario Quadrangle is summarized below.

Areas of Past Liquefaction

No areas of documented historic liquefaction in the Ontario Quadrangle are identified in this study. Areas showing evidence of paleoseismic liquefaction have not been reported.

Artificial Fills

No significant artificial fill sites in the Ontario Quadrangle have been identified in this study.

Areas with Existing Geotechnical Data

DMG's liquefaction potential evaluation of the Los Angeles County portion of the Ontario Quadrangle was based in large part on sufficient geologic and geotechnical data. The data indicate that potentially liquefiable soils exist in two separate areas, both falling within the City of Pomona.

Areas without Existing Geotechnical Data

Criteria developed by the Seismic Hazards Mapping Act Advisory Committee for areas lacking adequate geotechnical data was applied, along with limited geotechnical data, in identifying and zoning two separate areas within the City of Claremont.

SUMMARY

The project area is underlain almost entirely by clastic sedimentary deposits forming the large San Antonio Creek alluvial fan. Much of the upper 15-30 feet of the fan surface is composed of young sandy Quaternary deposits, that when saturated, are potentially liquefiable. Although depth to ground water in the region generally exceeds 100 feet, four isolated areas amounting to a combined total of one square mile contain near-surface, saturated, loose, sandy soils. These are identified on the Seismic Hazard Zone Map of Part of the Ontario 7.5-Minute Quadrangle, Los Angeles County, California.

Two of the four areas are in the west-central and southern parts of the City of Pomona. The zones measure 0.16- and 0.45-square mile, respectively. Within the boundaries of both zones, ground-water flow restrictions along the planes of two Quaternary faults, the San Jose (west-central Pomona) and Chino (south Pomona) faults, result in shallow water tables that saturate loose, sand-rich alluvial deposits. Zonation of these areas was based on the existence of adequate geotechnical data.

Zonation of a 0.2-square mile area in the south-central part of the City of Claremont reflects a shallow perched-water table that saturates young Quaternary gravel- and cobble-rich deposits that likely include interbedded sand. Zonation of this area was based mainly on criteria developed by the Seismic Hazards Mapping Act Advisory Committee for areas lacking adequate geotechnical data supported by limited geotechnical data.

A fourth area lying along the base of the San Gabriel Mountains in the northwestern part of the City of Claremont is zoned for potentially liquefiable sediments. The boundaries of this area extend northeastward into the adjoining Mt. Baldy Quadrangle, encompassing a total area of approximately one square mile. Zonation of this area was based on (1) criteria developed by the Seismic Hazards Mapping Act Advisory Committee for areas lacking adequate geotechnical data and (2) the high likelihood that the subsurface contains loose sandy sediments often saturated by ground water perched above a shallow, impervious bedrock surface.

ACKNOWLEDGMENTS

Staff assistance during the collection of subsurface data provided by the California Department of Transportation (Caltrans), Southern District office of the California Department of Water Resources, and Los Angeles Regional Water Quality Control Board is much appreciated. The author thanks John Tinsley, U. S. Geological Survey, for providing drilling log data. Special thanks are also given to Teri McGuire, Bob Moskovitz, and Scott Shepherd of DMG for their GIS operations support and to Barbara Wanish for graphic layout and reproduction of Seismic Hazard Zone maps.

REFERENCES

California Department of Conservation, Division of Mines and Geology, 2000, GEOTEC Database maintained by the Seismic Hazards Zone Mapping Program.

California State Mining and Geology Board, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.

California State Mining and Geology Board, in press, Criteria for delineating seismic hazard zones: California Department of Conservation, Division of Mines and Geology, Special Publication 118, 21 p.

Carson, S.E. and Matti, J.C., 1985, Contour map showing minimum depth to ground water, upper Santa River Valley, California, 1973-1979: U.S. Geological Survey Miscellaneous Field Studies Map MF-1802, 22 p., 2 plts., scale 1:48,000.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange, and Ventura counties, California: Bulletin of Seismological Society of America, v. 86, no. 5, p. 1,645-1,649.

Leighton and Associates, Inc., 1990, Hazard reduction in Los Angeles County: Technical Appendix to the Safety Element of the Los Angeles County General Plan, Department of Regional Planning, County of Los Angeles, vol. 2, plate 3, scale 1:125,000.

Mendenhall, W.C., 1908, Development of underground waters in the central coastal plain region of southern California: U.S. Geological Survey Water-Supply Paper 138, 160 p.

Morton, D.M. and Kennedy, M.P., 1989, A southern California digital 1:100,000-scale geologic map series: The Santa Ana Quadrangle, The first release: Geological Society of America Abstracts with Programs v. 21, no. 6, p. A107-A108.

National Research Council, 1985, Liquefaction of soils during earthquakes: National Research Council Special Publication, Committee on Earthquake Engineering, National Academy Press, Washington, D.C., 240 p.

Petersen, M.D., Cramer, C.H., Bryant, W.A., Reichle, M.S. and Toppozada, T.R., 1996, Preliminary seismic hazard assessment for Los Angeles, Ventura, and Orange counties, affected by the 17 January 1994 Northridge earthquake: Bulletin of the Seismological Society of America, v. 86, no. 1B, p. S247-S261.

Seed, H.B. and Idriss, I.M., 1971, Simplified procedure for evaluating soil liquefaction potential: Journal of the Soil Mechanics and Foundations Division of ASCE, v. 97: SM9, p. 1,249-1,273.

Seed, H.B., Idriss, I.M. and Arango, Ignacio, 1983, Evaluation of liquefaction potential using field performance data: Journal of Geotechnical Engineering, v. 109, no. 3, p. 458-482.

Seed, H.B., Tokimatsu, Kohji, Harder, L.F. and Chung, R.M., 1985, Influence of SPT procedures in soil liquefaction resistance evaluations: Journal of Geotechnical Engineering, ASCE, v. 111, no. 12, p. 1,425-1,445.

Seed, R.B. and Harder, L.F., 1990, SPT-based analysis of cyclic pore pressure generation and undrained residual strength: Proceedings of the H. Bolton Seed Memorial Symposium, v. 2, p. 351-376.

Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: California Geology, v. 49, no. 6, p. 147-150.

Southern California Areal Mapping Project, 1999, Unpublished digital geologic map compilation of the Ontario 7.5-minute Quadrangle, digitized at scale of 1:24000.

Tinsley, J.C., Youd, T.L., Perkins, D.M. and Chen, A.T.F., 1985, Evaluating liquefaction potential, *in* Ziony, J.I., *editor*, Evaluating earthquake hazards in the Los Angeles region -- an earth science perspective: U.S. Geological Survey Professional Paper 1360, p. 263-316.

Wills, C.J. and Silva, Walter, 1998, Shear wave velocity characteristics of geologic units in California: Earthquake Spectra, v. 14, in press.

Youd, T.L., 1991, Mapping of earthquake-induced liquefaction for seismic zonation: Earthquake Engineering Research Institute, Proceedings, Fourth International Conference on Seismic Zonation, v. 1, p. 111-138.

Youd, T.L. and Idriss, I.M., 1997, *editors*, Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: National Center for Earthquake Engineering Research Technical Report NCEER-97-0022, 276 p.

Youd, T.L. and Perkins, D.M., 1978, Mapping liquefaction-induced ground failure potential: Journal of Geotechnical Engineering, v. 104, p. 433-446.

SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Ontario 7.5-Minute Quadrangle, Los Angeles County, California

By
Florante G. Perez, Allan G. Barrows, Timothy P. McCrink, and Rick I. Wilson

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Ontario 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Areas most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, in loose soils, and on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the Ontario Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, the State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Ontario Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Ontario Quadrangle covers an area of about 62 square miles of mostly gently sloping terrain that straddles the Los Angeles and San Bernardino County boundary. The 15-square-mile area of valley-floor terrain evaluated in this study lies within the Los Angeles County part of the quadrangle. (Federal funding for the program limits the investigation to Los Angeles, Orange, and Ventura counties; therefore, the County of San Bernardino is not covered by the current study). The study area encompasses a small part of the upper Santa Ana River valley, which is a roughly 40-mile long, 10-mile wide structural basin that extends along the southern base of the mountains between Pomona and San Bernardino. Just north of the Ontario Quadrangle, in the Mt. Baldy Quadrangle, the San Gabriel Mountains rise abruptly above the valley floor. Exposed within this steep, rugged terrain is a complex assemblage of Precambrian through Cretaceous igneous and metamorphic rocks that has been thrust southward over the adjacent basin.

The notable drainage emanating from the San Gabriel Mountains and flowing through the project area is San Antonio Creek. Materials eroded from the mountains and deposited in the valley via this drainage and its tributaries have formed a large alluvial fan upon which lie the cities of Claremont and Pomona in Los Angeles County.

Except for 1.5-square miles in the southwestern corner of the quadrangle occupied by the Puente Hills (in San Bernardino County) and a tiny projection of the mountain front into the northwesternmost corner, the project area consists of relatively flat, densely populated land. Major transportation routes traversing the Ontario Quadrangle include the San Bernardino Freeway (I-10) and the Pomona Freeway (State Highway 60). Major east-west streets in the project area include Base Line Road, Foothill Boulevard, Arrow Highway, and Holt Avenue. Important north-south streets include Garey, Towne, and Indian Hill boulevards.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

For the Ontario Quadrangle, a geologic map was compiled and digitized by the Southern California Areal Mapping Project (SCAMP, 1999; Morton and Kennedy, 1999). The digital geologic map obtained from SCAMP was modified to reflect the most recent mapping in the area. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of landslides was noted.

Basement rocks of Mesozoic age, consisting of quartz diorite and granodiorite (Kqd), are exposed only in the extreme northwestern corner of the quadrangle. In the southwestern corner of the quadrangle, the Yorba Member (Tpy) of the middle-upper Miocene Puente

Formation occupies the northeastern slope of Puente Hills, which are almost entirely in San Bernardino County in this quadrangle. The Yorba Member is made up of interbedded sandy and diatomaceous siltstone accompanied by thin beds of limestone and thin-bedded to massive sandstone.

The extensive alluvial fan formed by San Antonio Creek and its tributaries is made up of fine- to very coarse-grained sedimentary deposits that include active channel wash (Qw), young alluvial fan deposits (Qyf1, Qyf2, Qyf3), older alluvial fan deposits (Qof), and very old alluvial fan deposits (Qvof). A more detailed discussion of the Quaternary deposits in the Ontario Quadrangle can be found in Section 1.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they first must be ranked based on their overall shear strength. Typically, shear strength data for the rock units identified on the geologic map are obtained from geotechnical reports prepared by consultants on file with local government permitting departments. Shear test data were unavailable because of the generally low relief and limited exposures of bedrock within the Ontario Quadrangle. Instead, shear strength values were obtained from the San Dimas Quadrangle to the west, and the Glendora Quadrangle to the northwest (see Appendix A). Geologic units were grouped on the basis of average angle of internal friction (average f) and lithologic character. The results of the grouping of geologic materials in the Ontario Quadrangle are in Tables 2.1 and 2.2.

ONTARIO QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number Tests	Mean/Median phi (deg)	Mean/Median C (psf)	Equivalent Formation in Ontario Quad	Phi Values Used in Stability Analysis
GROUP 1	gr	12(G)	38.5/37.5	156/178	Kgd	**37**
GROUP 2	Qof/Qyf Qa*	50(SD) 46(G)	32.3 33.7/34.5	259/200 294/300	Qw, Qyfa, Qyfcs Qyfga, Qyf2ga Qyf1b, Qyf3b Qofga. Qofb, Qvofag	**33**
GROUP 3	Tpy	17(SD)	29.9	259/200	Tpy	**28**
GROUP 5	Qls	-	-	-	Qls	**14**

SD = Data from the San Dimas Quadrangle
G = data from the Glendora Quadrangle

Table 2.1. Summary of the Shear Strength Statistics for the Ontario Quadrangle.

ONTARIO QUADRANGLE SHEAR STRENGTH GROUPS			
Group 1	**Group 2**	**Group 3**	**Group 4**
Kqd	Qw,Qyfa,Qyfcs Qyfga,Qyf2ga Qyf1b,Qyf3b, Qofga,Qofb,Qvofag	Tpy	Qls

Table 2.2. Summary of the Shear Strength Groups for the Ontario Quadrangle.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of existing landslides in the Ontario Quadrangle was prepared by reviewing published maps and reports showing or discussing landslides, (for example, Tan, 1988) and combining field observations, analysis of aerial photos (see References for list of air photos used), and interpretation of landforms on current and older topographic maps. The landslide inventory map was digitized and information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic units was compiled in a database. A version of this landslide inventory is included with Plate 2.1.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the Ontario Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	7
Modal Distance:	2.5 to 16 km
PGA:	0.46 to 0.74 g

The strong-motion record selected for the slope stability analysis in the Ontario Quadrangle was the Corralitos record from the magnitude 6.9 (M_w) 1989 Loma Prieta earthquake (Shakal and others, 1989). This record had a source to recording site distance of 5.1 km and a peak ground acceleration (PGA) of 0.64 g. The selected strong-motion record was not scaled or otherwise modified prior to its use in the analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.086g, 0.133g and 0.234g. Because these yield acceleration values are derived from the design strong-motion record, they represent the ground shaking opportunity thresholds that are significant to the Ontario Quadrangle.

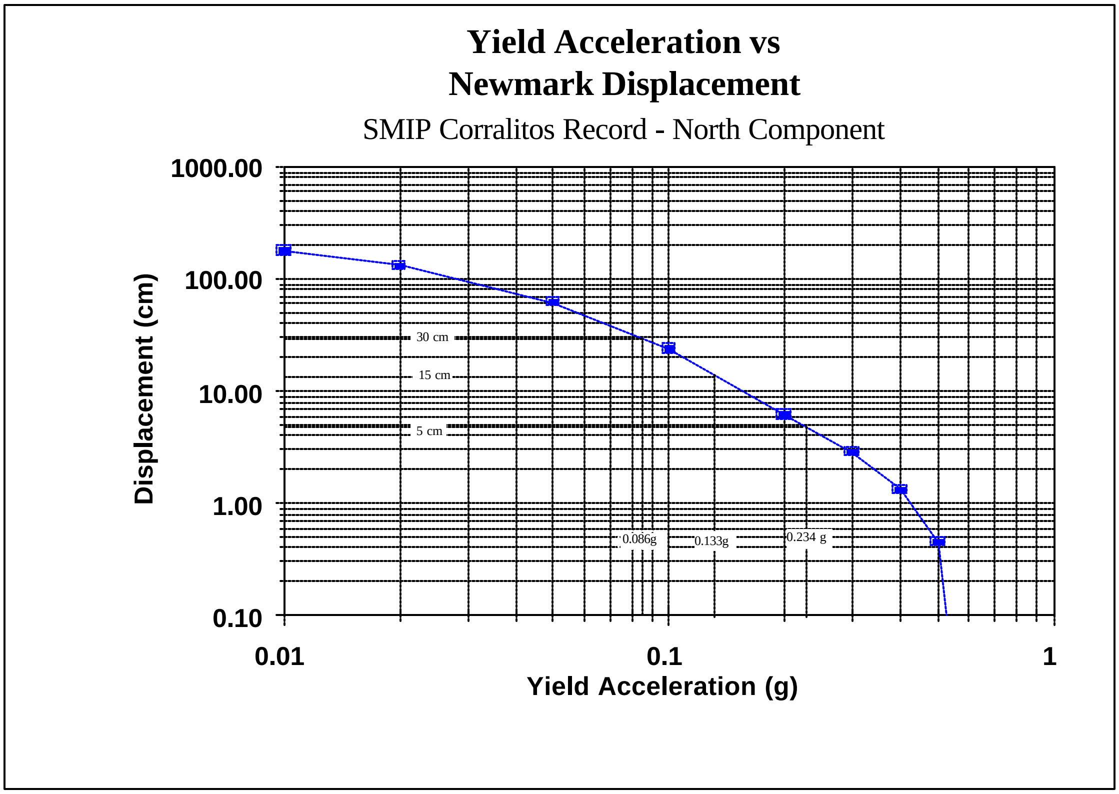


Figure 2.1. Yield Acceleration vs. Newmark Displacement for the 1989 Loma Prieta Earthquake Corralitos Record. Record from California Strong Motion Instrumentation Program (CSMIP) Station 57007.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. To calculate slope gradient for the terrain within the Ontario Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1995). This DEM, which was prepared from the 7.5-minute quadrangle contours, has a 10-meter horizontal resolution and a 7.5-meter vertical accuracy. Surrounding quadrangle DEMs were merged with the Ontario DEM to avoid the loss of data at the quadrangle edges when the slope calculations were performed. A peak and pit smoothing process was then performed to remove errors in the elevation points.

To update the topographic base map, areas that have undergone large-scale grading as a part of residential development in the hilly portions of the Ontario Quadrangle were identified. Using 1:40,000-scale NAPP photography taken in 1994 and 1995, photogrammetric DEMs covering the graded areas were prepared by the U.S. Bureau of Reclamation with ground control obtained by DMG. The photogrammetric DEMs were then merged into the USGS DEM, replacing the areas of out-dated elevation data. Plate 2.2 shows those areas where the topography is updated to 1994-95 grading conditions.

A slope-gradient map was made from the combined DEMs using a third-order, finite difference, center-weighted algorithm (Horn, 1981). This map was used in conjunction with the geologic strength map in preparation of the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield acceleration calculated by Newmark's equations represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.086g, expected displacements could be greater than 30 cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.086 and 0.133g a MODERATE (M on Table 2.3) hazard potential was assigned, between 0.133 and 0.234g a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.234g a VERY LOW (VL on Table 2.3) potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

Ontario Quadrangle
Hazard Potential Matrix

Geologic Material Strength	I 0 to 11% **0 to 6°**	II 12 to 16% **7 to 9°**	III 17 to 39% **10 to 21°**	IV 40 to 43% **22 to 23°**	V 44 to 54% **24 to 28°**	VI 55 to 65% **29 to 33°**	VII > 65% **>33°**
Group 1	VL	VL	VL	VL	L	M	H
Group 2	VL	VL	VL	L	M	H	H
Group 3	VL	VL	L	M	H	H	H
Group 4	L	M	H	H	H	H	H

SLOPE GRADIENT CATEGORY

Table 2.3. Hazard Potential Matrix for Earthquake-Induced Landslides in the Ontario Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (1996). Under those criteria, earthquake-induced landslide zones are areas meeting one or both of the following:

1. Areas identified as having experienced landslide movement in the past (including all mappable landslide deposits and source areas), and, where possible, areas known to have experienced earthquake-induced landsliding during historic earthquakes.

2. Areas where geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996) the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic strength group 4 is always included in the zone (mapped landslides); strength group 3 above 16%; strength group 2 above 39%; and strength group 1, the strongest rock types, were zoned for slope gradients above 43%. This results in roughly 0.13% of the land in the quadrangle lying within the hazard zone representing 0.5% of the area mapped.

ACKNOWLEDGMENTS

The authors thank Dean Montgomery, George Knight, and Monte Lorenz of the U.S. Bureau of Reclamation for supplying the topographic data for areas of mass grading in the quadrangle. Technical review of the methodology was provided by Bruce Clark, Randy Jibson, Robert Larson, Scott Lindvall, and J. David Rogers, who are members of the State Mining and Geology Board's Seismic Hazards Mapping Act Advisory Committee Landslides Working Group. At DMG, special thanks to Scott Shepherd, Teri McGuire, and Bob Moskovitz for their Geographic Information System operations support and Barbara Wanish for designing and plotting the graphic displays associated with the hazard zone map and this report.

REFERENCES

Brabb, E.E., 1983, Map showing direction and amount of bedding dip of sedimentary rocks in San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I-1257C, 1 sheet, scale 1:62,500.

California State Mining and Geology Board, 1996, Criteria for delineating earthquake-induced landslide hazard zones: Unpublished California State Mining and Geology Board document developed by the Seismic Hazards Mapping Act Advisory Committee.

California State Mining and Geology Board, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange and Ventura counties, California: Bulletin of the Seismological Society of America, v. 85, no. 5, pp. 1645-1649.

Horn, B.K.P., 1981, Hill shading and the reflectance map: Proceedings of the IEEE, v. 69, no. 1, p. 14-47.

Jibson, R.W., 1993, Predicting earthquake-induced landslide displacements using Newmark's sliding block analysis: Transportation Research Board, National Research Council, Transportation Research Record 1411, 17 p.

Keefer, D.K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, v. 95, no. 4, p. 406-421.

McCrink, T.P. and Real, C.R., 1996, Evaluation of the Newmark method for mapping earthquake-induced landslide hazards in the Laurel 7-1/2 minute Quadrangle, Santa Cruz County, California: California Division of Mines and Geology Final Technical Report for U.S. Geological Survey Contract 143-93-G-2334, U.S. Geological Survey, Reston, Virginia, 31 p.

Morton, D.M. and Kennedy, M.P., 1989, A southern California digital 1:100,000-scale geologic map series: The Santa Ana Quadrangle, The first release: Geological Society of America Abstracts with Programs v. 21, no. 6, p. A107-A108.

Newmark, N.M., 1965, Effects of earthquakes on dams and embankments: Geotechnique, v. 15, no. 2, p. 139-160.

Petersen, M.D., Cramer, C.H., Bryant, W.A., Reichle, M.S. and Toppozada, T.R., 1996, Preliminary seismic hazard assessment for Los Angeles, Ventura, and Orange counties, California, affected by the January 17, 1994 Northridge earthquake: Bulletin of the Seismological Society of America, v. 86, no. 1B, p. S247-S261.

Shakal, A., Huang, M., Reichle, M., Ventura, C., Cao, T., Sherburne, R., Savage, M., Darragh, R. and Peterson, C., 1989, CSMIP strong-motion records from the Santa Cruz Mountains (Loma Prieta), California earthquake of 17 October 1989: California Department of Conservation, Division of Mines and Geology, Office of Strong Motion Studies Report OSMS 89-06, 196 p.

Smith, T.C., 1996, Preliminary maps of seismic hazard zones and draft guidelines for evaluating and mitigating seismic hazards: California Geology, v. 49, no. 6, p. 147-150.

Southern California Areal Mapping Project, 1999, Unpublished digital geologic map compilation of the Ontario 7.5-minute Quadrangle, digitized at scale of 1:24000.

Tan, S. S., 1988, Landslide hazards in the Puente and San Jose Hills, Southern California, Landslide Hazard Identification Map No. 12: California Department of

Conservation, Division of Mines and Geology, Open-File Report 88-21, map scale 1:24000.

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.

Youd, T.L., 1980, Ground failure displacement and earthquake damage to buildings: American Society of Civil Engineers Conference on Civil Engineering and Nuclear Power, 2d, Knoxville, Tennessee, 1980, v. 2, p. 7-6-2 to 7-6-26.

AIR PHOTOS

USGS Project GS-VEZS, I.K.Curtis Services, Inc. October 20, 1980 Aerial Photographs, flight1, frames 63-65, 108-109, and 233-235, flight 2, frames 23-25, black and white, vertical, approximate scale 1:14000.

USGS (U.S. Geological Survey), NAPP Aerial Photography, June 1, 1994, flight 6866, frames 102-105, frames 123-127, May 28, 1994, flight 6851, frame 152, black and white, vertical, approximate scale 1:40000.

APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
San Dimas Quadrangle	**67**
Glendora Quadrangle	**58**

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Ontario 7.5-Minute Quadrangle, Los Angeles County, California

By

Mark D. Petersen, Chris H. Cramer, Geoffrey A. Faneros, Charles R. Real, and Michael S. Reichle

California Department of Conservation Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles.

They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

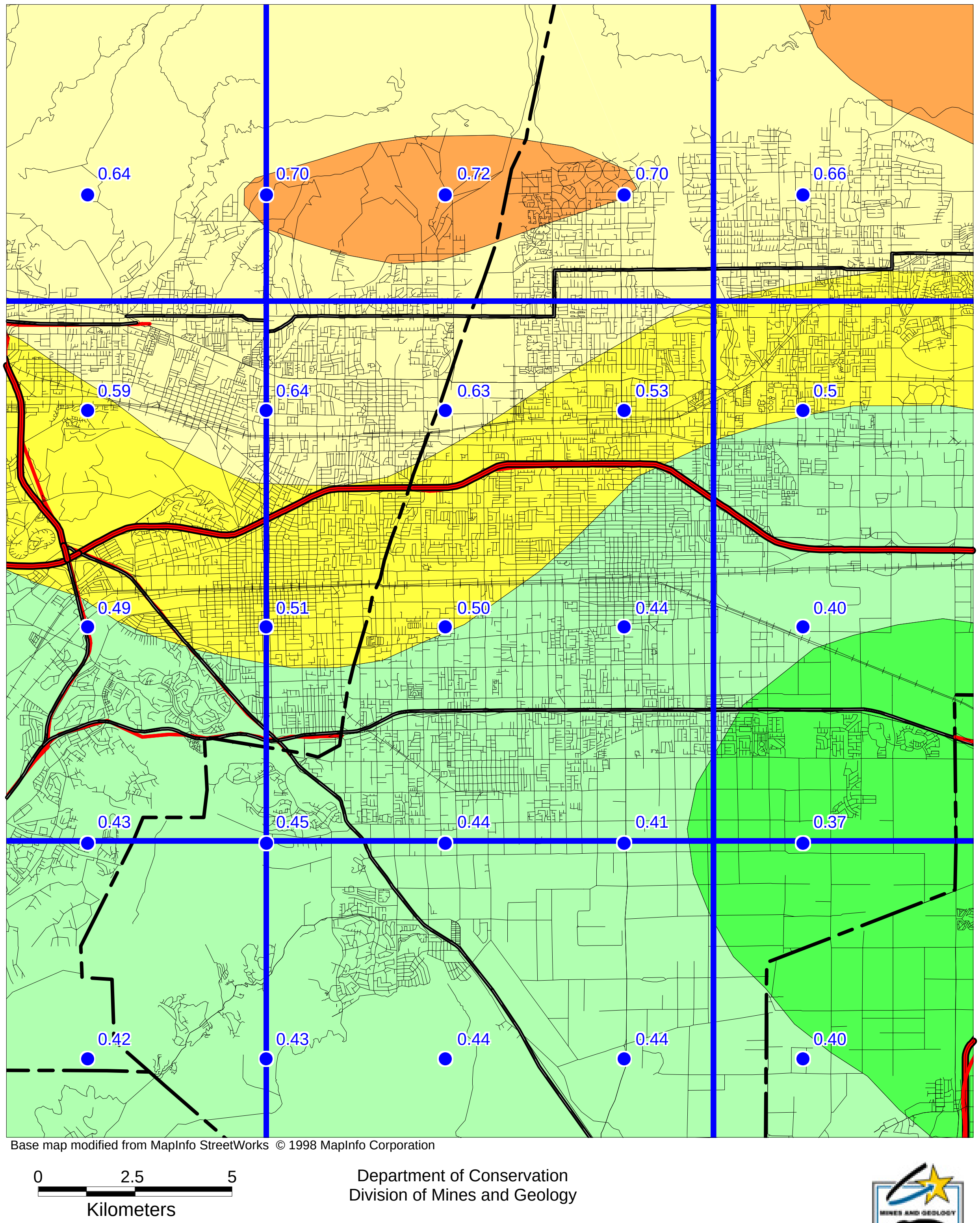
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent

ONTARIO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Department of Conservation
Division of Mines and Geology

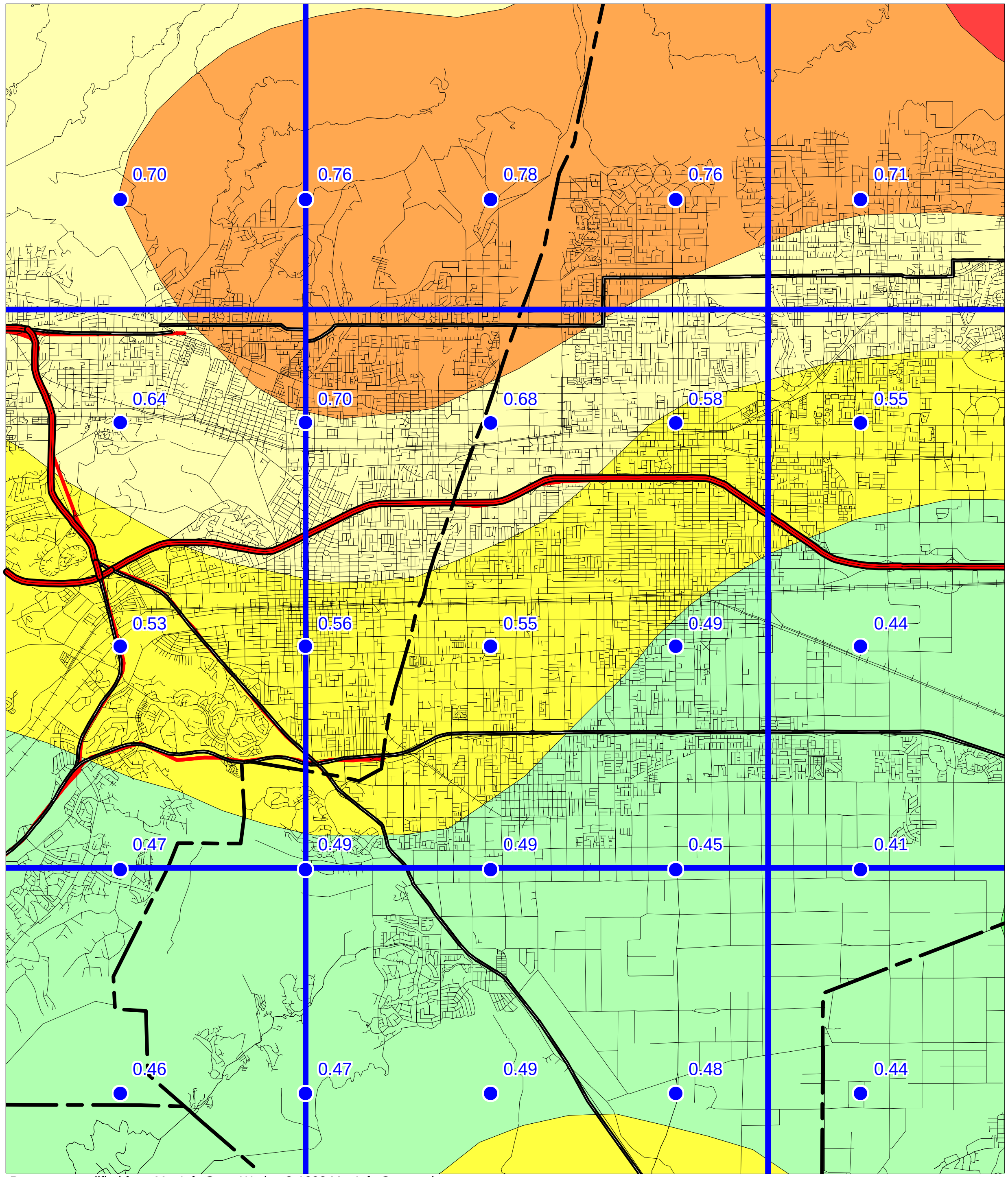
Figure 3.1

ONTARIO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map modified from MapInfo StreetWorks © 1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

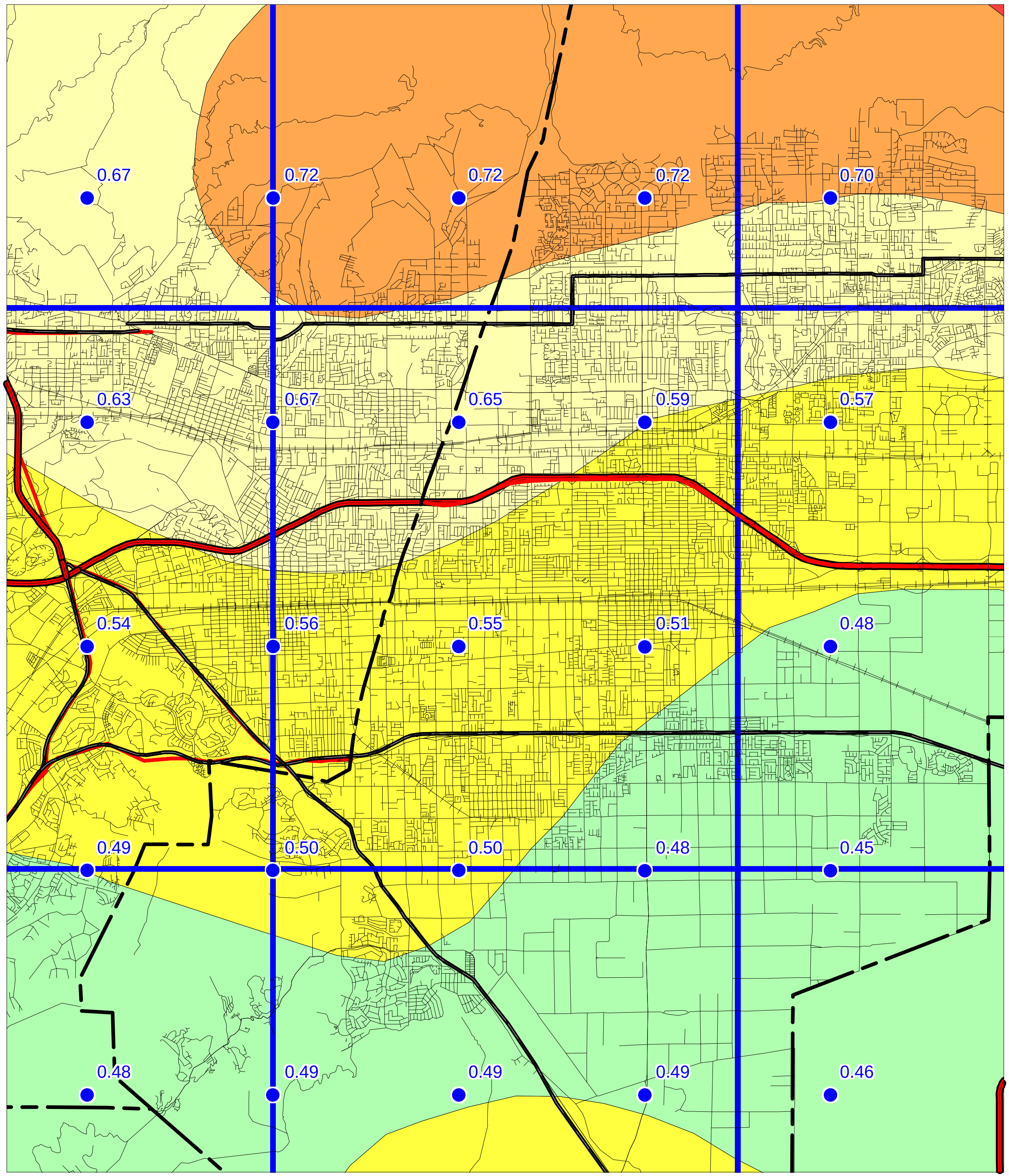
Figure 3.2

ONTARIO 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

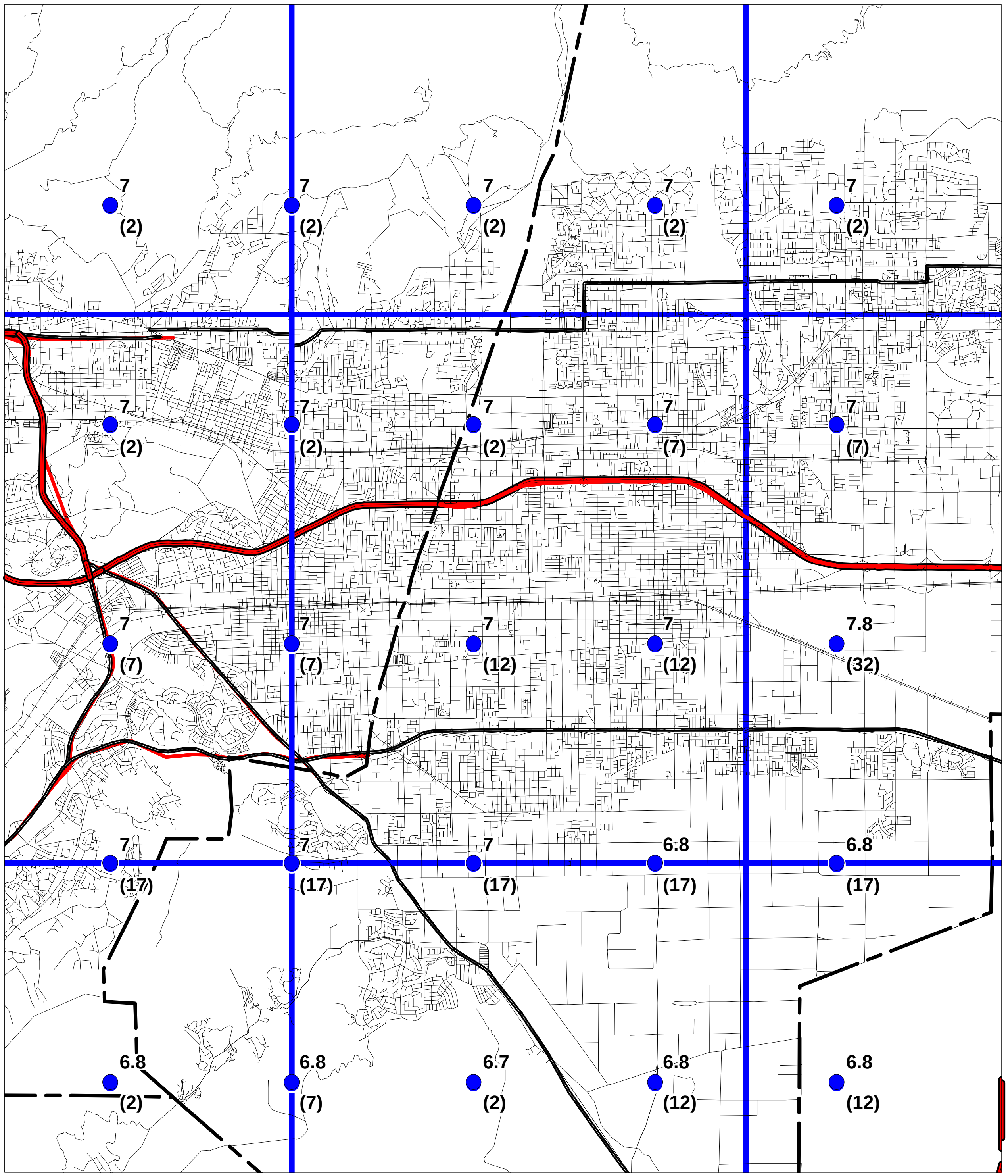
1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation

ONTARIO 7.5 MINUTE QUADRANGLE AND PORTIONS OF
ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.4

of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the “importance” or sensitivity of the proposed building with regard to occupant safety.

REFERENCES

Boore, D.M., Joyner, W.B. and Fumal, T.E., 1997, Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra: Seismological Research Letters, v. 68, p. 154-179.

California State Mining and Geology Board, 1997, Guidelines for evaluating and mitigating seismic hazards in California: California Department of Conservation, Division of Mines and Geology, Special Publication 117, 74 p.

Campbell, K.W., 1997, Attenuation relationships for shallow crustal earthquakes based on California strong motion data: Seismological Research Letters, v. 68, p. 180-189.

Cramer, C.H. and Petersen, M.D., 1996, Predominant seismic source distance and magnitude maps for Los Angeles, Orange and Ventura counties, California: Bulletin of the Seismological Society of America, v. 85, no. 5, p. 1645-1649.

Cramer, C.H., Petersen, M.D. and Reichle, M.S., 1996, A Monte Carlo approach in estimating uncertainty for a seismic hazard assessment of Los Angeles, Ventura, and Orange counties, California: Bulletin of the Seismological Society of America, v. 86, p. 1681-1691.

International Conference of Building Officials (ICBO), 1997, Uniform Building Code: v.2, Structural engineering and installation standards, 492 p.

Jennings, C.W., *compiler*, 1994, Fault activity map of California and adjacent areas: California Department of Conservation, Division of Mines and Geology, California Geologic Data Map Series, map no. 8.

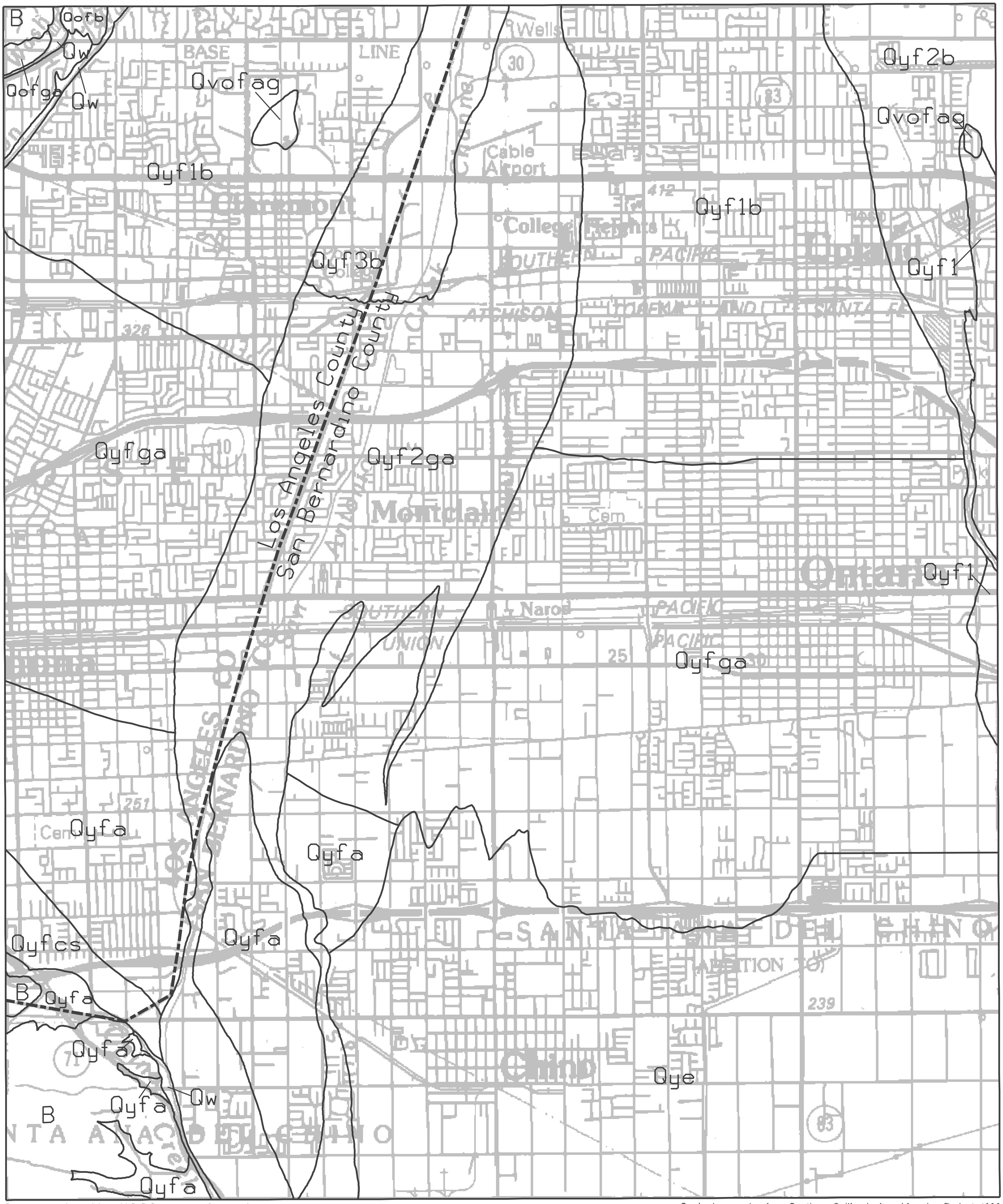
Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A. and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open-File Report 96-08; also U.S. Geological Survey Open-File Report 96-706, 66 pp.

Sadigh, K., Chang, C.-Y., Egan, J.A., Makdisi, F. and Youngs, R.R., 1997, SEA96- A new predictive relation for earthquake ground motions in extensional tectonic regimes: Seismological Research Letters, v. 68, p. 190-198.

Wilson, R.C. and Keefer, D.K., 1983, Dynamic analysis of a slope failure from the 1979 Coyote Lake, California, Earthquake: Bulletin of the Seismological Society of America, v. 73, p. 863-877.

Youd, T.L. and Idriss I.M., 1997, Proceedings of the NCEER workshop on evaluation of liquefaction resistance of soils: Technical Report NCEER-97-0022, 40 p.

Youngs, R.R., Chiou, S.-J., Silva, W.J. and Humphrey, J.R., 1997, Stochastic point-source modeling of ground motions in the Cascadia Region: Seismological Research Letters, v. 68, p. 74-85.



Base map enlarged from U.S.G.S. 30 x 60–minute series

Geologic mapping from Southern California Area Mapping Project, 1999

Plate 1.1 Quaternary Geologic Map of the Ontario Quadrangle.
See Geologic Conditions section in report for descriptions of the units.
B = Pre–Quaternary bedrock.

ONE MILE

Scale

Base map enlarged from U.S.G.S. 30 x 60–minute series

Groundwater contours modified from Carson and Matti (1985)

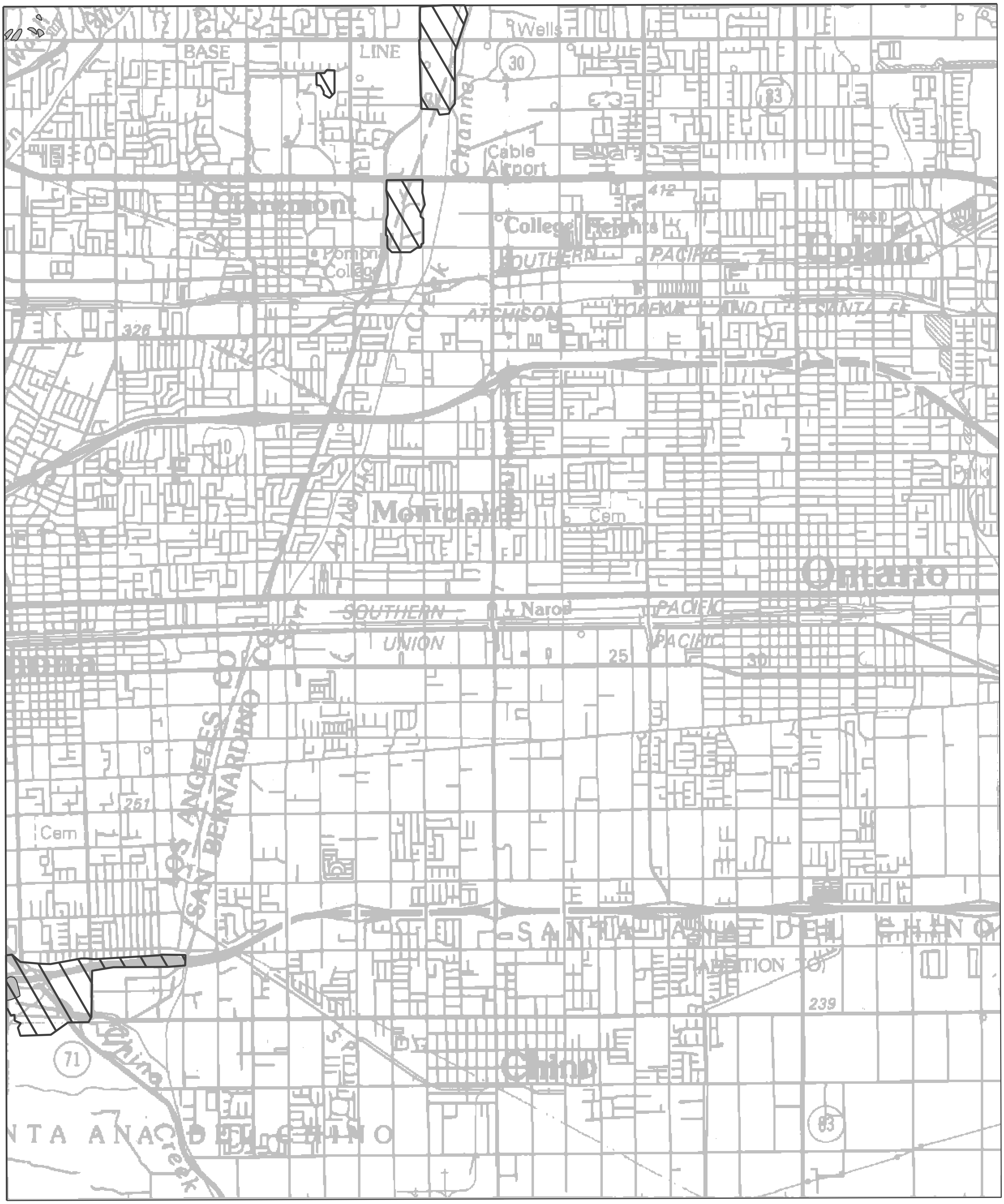
Plate 1.2 Historically Highest Ground Water Levels and Borehole Log Data Locations in the Los Angeles County Part of the Ontario Quadrangle.

● Borehole Site

30 Depth to ground water in feet

ONE MILE

Scale



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Landslide inventory, Shear Test Sample Locations, Ontario Quadrangle.

landslide

areas of significant grading

ONE MILE

SCALE